Interactions between reproduction and fisheries in Bluefish, *Pomatomus saltatrix* (Pomatomidae), from Gulf of Gabes (Tunisia)

by

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ABSTRACT. - The bluefish, *Pomatomus saltatrix* (L. 1766), in the Gulf of Gabes (southeast of Tunisia) is a gonochoric species that reach first sexual maturity at the age of two years by a standard length (SL50) approaching 17.6 cm. Weekly changes in the Gonad-Somatic Index showed that spawning occurs in autumn (Oct-Nov). To get ready to reproduction, the bluefish saves some lipid reserves in muscles as well as in liver. Thus, the fishery season that spreads from 1st May to 31st August is well chosen because, on the one hand it corresponds to the period when the bluefish is in its best physiological state and on the other hand it is closed two months before the spawning. Furthermore, the minimal legal size of capture (22 cm SL) lets a safety margin of 4.4 cm allowing up to 50% of the population to reproduce at least once in their life. Therefore, the law in force always remains valid and deserves to be more reinforced.

RÉSUMÉ. - Interactions entre la reproduction et la pêche du tassergal, *Pomatomus saltatrix* (Pomatomidae), du golfe de Gabès (Tunisie).

Le tassergal, *Pomatomus saltatrix* (L. 1766), du golfe de Gabès (sud-est de la Tunisie) est une espèce gonochorique qui atteint sa première maturité sexuelle à l'âge de deux ans, à une longueur standard (LS 50) de l'ordre de 17,6 cm. L'analyse des variations hebdomadaires du Rapport Gonado-Somatique (RGS) a montré que la ponte se déclenche en automne (octobre-novembre). Pour se préparer à la reproduction, le tassergal épargne des réserves lipidiques aussi bien au niveau des muscles qu'au niveau du foie. Ainsi, la saison de pêche qui s'étend du 1er mai au 31 août est bien choisie parce qu'elle correspond à la période où la chair du tassergal est bien appréciée par les consommateurs, d'une part, et elle est close deux mois avant la ponte, d'autre part. En outre, la taille minimale de capture autorisée (22 cm LS) laisserait une marge de sécurité de 4,4 cm, permettant ainsi à 50% des individus de la population de se reproduire au moins une fois dans leur vie. Par conséquent, la réglementation en vigueur reste toujours valable et mérite d'être appliquée avec vigilance.

Key words. - Pomatomidae - *Pomatomus saltatrix* - MED - Tunisia - Gulf of Gabes - Reproduction - Fishing.

The bluefish, *Pomatomus saltatrix* (Linnaeus, 1766), is a migratory marine fish with a large geographical distribution (Wilk, 1977). Breeding in the majority of moderate and hot areas, it abounds in the zone where the trophic climatic conditions are the most favourable (Le Page, 1995). Having an important commercial value, this species is exploited by various types of fishing tackles. Being pelagic, the bluefish is especially targeted by an appropriate gear during a fishery season determined by the authorities concerned. Thus, in some countries like Brazil, Australia and Tunisia, the fishing of the bluefish is subject to some regulations to allow the proper management of this resource, which tempts fishermen.

Scientific research has been concerned with various aspects of bluefish biology. Sabates and Martin (1993) studied the reproduction and abundance of the bluefish in the north-western part of the Mediterranean Sea. Harding and Mann (2001) did some work on the diet and habitat of the species. Salerno *et al*. (2001) got interested in estimating the age, the growth and the maturity of the bluefish of the north-eastern coasts of the United States. As for the structure of the stock, the fishery, the mortality and the strategy of the bluefish, these topics have been dealt with by Haimovici and Krug (1982), Graves *et al*. (1992) and Young *et al*. (1999).

In Tunisia, bluefish is present along all coasts but it abounds in the Gulf of Gabes in the south-eastern part of the country. Previously, it was caught together with other small pelagic fish such as sardines and mackerels. Then, seeing its commercial importance, it became a target species and its production got more emphasis. Since the 90s a fishery management plan has been developed and the fishing of bluefish was submitted to authorized measures, which have been taken empirically. Ever since then, the professionals have been asking for the partial or total modification of the restrictions and, each year, a polemic arises over the bluefish. Imperatively, we undertook to study the biology of

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the bluefish in the Gulf of Gabes to reconcile its exploitation with its preservation in order to really manage the stock. Here, we present the analysis of the different parameters of reproduction and we examine the landings of the bluefish in the present conditions.

MATERIALS AND METHODS

Zone of study

The Gulf of Gabes, situated in the Southeast of Tunisia, spreads from Cape Kapoudia (35th parallel) to the Tunisian-Lybian borders (Fig. 1). It is characterized by a hot climate with an average annual temperature of 19.5°C (Azouz, 1971), a high percentage of sunshine varying between 62% and 87% (PNUE, 1996), a low rainfall (less than 400 mm) and an irregular current direction controlled by the wind and the tide (Hamza, 2003). The relief of this gulf reflects the landscapes (steppe and plain) of the rear country (Poizat, 1970). The continental shelf reaches some surfaces uncommon in the Mediterranean (Zaouali, 1993) and includes vast herbals that constitute the spawning-grounds and nurseries for several vertebrates and invertebrates (Bradaï, 2000). This maritime area conceals abundant resources of species with important commercial value exploited by varied fishing techniques. Indeed, in spite of the importance of the fishing fleet in the region, artisanal fishing is very prosperous because it is made easy by the particular geomorphology of the zone: shoals and vast platforms (Hamza, 2003).

Restrictions

The fishery of the bluefish has been managed since 28 September 1995 by technical measures including spatial and temporal closures and gear restrictions including minimum mesh sizes and minimum landing size. We cite hereafter the most essential of these measures. In the Gulf of Gabes, several types of gears can practise the fishing of the bluefish all year round, but the legal size of capture (standard length) must not be lower to 22 cm. The trawling is still forbidden at depths inferior to 50 m. The use of the purse-seines is only allowed from 1st May to 31st August (fishery season of the bluefish) in depths greater than 20 m. The stretched meshes of the nets and their accessories must measure at least 24 mm.

Sampling

To gather information on bluefish fishery we participated in some sea journeys on board of seiners and trawlers. We sampled commercial landings from 1999 to 2003 from three fleets (gill netters, purse seiners and trawlers) in the main harbours in the Gulf of Gabes to analyse the sizes (TL) of landed specimens. Besides, the General Directorate of the Fishing in Tunisia (GDFT) provided us with the statistical data on monthly fishing and total landings by gear.

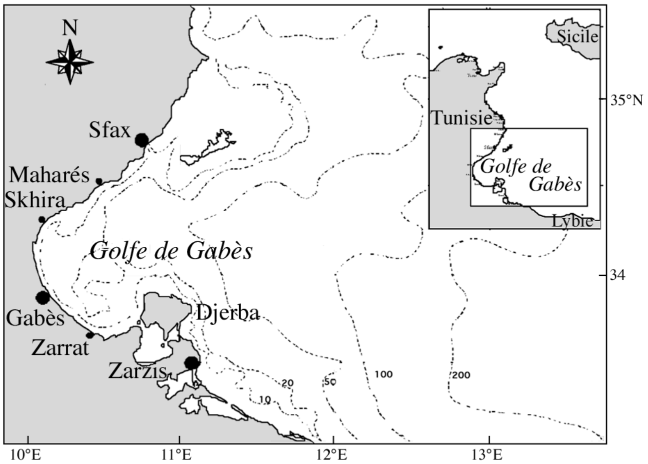


Figure 1. - Geographical position of the Gulf of Gabes (Tunisia). *[Position géographique du golfe de Gabès (Tunisie).]*

The study of the reproduction was carried out on a sample of 577 individuals weekly collected from October 1998 to January 2000 from commercial catches in the Gulf of Gabes. The total length (TL) and standard length (SL) were measured in mm. The total weight (TW) and eviscerated weight (EW) were measured in gram. The gonads and livers were measured at the nearest 10 mg. Sex and degree of sexual maturity were determined macroscopically when the gonad was developed, and microscopically when it was minute.

We analyzed the changes in sex proportion according to sizes and seasons. Sex proportion was calculated by using the formulas:

Proportion of males: $(\%M) = (M/M+F)*100$,

Proportion of females: $(\%F) = (F/M+F)*100$,

where M = number of males and F = number of females.

We analysed weekly changes in the Gonad-Somatic Index (GSI) to determine spawning period of the species. This index is given by:

$GSI = (GW/EW)*100$,

where GW = gonad weight; EW = the eviscerated weight.

The weekly variations in the GSI indicate the evolution in weight of the gonads during the year and permit to describe the various stages of sexual cycle.

Accumulation and depletion of resources for bluefish in the Gulf of Gabes was studied through the analysis of monthly changes of Hepatic-Somatic Index (HSI) and of those in the condition coefficient (K) as liver and muscles are two store organs. These indexes were calculated as follows:

$HSI = (LW/EW)*100$,

$K = (EW/SL^3)*100$,

where LW = liver weight in g; EW = eviscerated weight in g; SL = standard length in cm.

To estimate size at first sexual maturity (L50), we calculated the proportion (Pi) of mature individuals by sex and by size class.

$Pi = (Mi/Iei)*100$,

where Mi = number of mature individuals in the size i; Iei = number of examined individuals in the same size class i.

The obtained data were fitted to a logistical function by using the software 'FSAS' (Saul *et al*., 1988). This function has the advantage of estimating with precision the lengths L25, L50, L75 that are often required by most soft-wares to analyse the stocks of fish (Ghorbel *et al*., 1996). The equation used was:

$P = 1/1+e^{-r(L-L50)}$,

where P = proportion of mature individuals; L = standard length corresponding to the proportion (P); r = constant; L50 = standard length of 50% mature (size at first maturity).

The results were tested using the χ^2 test (Lamotte, 1967).

The age at first sexual maturity has been determined using the formula deduced from the Von Bertalanffy (1934) growth equation:

$t = t_0\text{-}1/k\{\mathrm{Log}[(L_\infty - L_t) \_L_\infty)]\}$,

where t = age at first maturity; L_t = length at the age t; L_∞ = asymptotic length; k = growth coefficient; and t_0 = the age when length would theoretically be zero.

These parameters (L_∞, k and t_0) were determined by scalimetry (Tab. I).

The relationships between standard length (SL) and total length (TL) for bluefish (combined sexes) in the Gulf of Gabes are the following:

$TL = 1.1440\ SL^{1.0178}$ ($r^2 = 0.9989$);

$SL = 0.8954\ TL^{0.9788}$ ($r^2 = 0.9886$).

To analyse bluefish landings in the Gulf of Gabes in 2002 and 2003, the annual catches of each gear (gill-netters, purse-seiners, trawlers) were distributed in three temporal strata of four months each since the fishery season lasts four months, in order to have homogenous data:

- pre-fishery season: January-April;
- fishery season: May-August;
- post-fishery season: September-December.

The number of individuals caught by size class was estimated by multiplying the number of individuals sampled by the extrapolation factor (F_{ext}) relative to every stratum:

$$F_{ext} = \frac{W_{land}}{W_{SI}}$$

where W_{land} = weight of the landings by stratum and W_{SI} = total weight of individuals sampled by stratum, calculated by using the parameters 'a' and 'b' of the relationship TW on TL (i.e. $TW = a\ TL^b$), where TW = total weight (dependent variable); TL = total length (independent variable); 'a' and 'b' are constants to be estimated usually by nonlinear least squares regression.

For bluefish in the Gulf of Gabes $TW = 0.0110TL^{2.9507}$, $r^2 = 0.9867$, for combined sexes.

The percentage of mature individuals in each stratum is the total of the percentages calculated by size class by using the equation ($P = 1/1+e^{-r(L-L50)}$) (see above).

To estimate, in each stratum, the mean total length (TL_m) and the mean total weight (TW_m) we used the formula:

$$X_m = \frac{\sum_{i=1}^{k} f_i X_i}{\sum_{i=1}^{k} f_i}$$

where $X_m = TL_m$ or TW_m and X_i = TL or TW by size class.

Table I. - Theoretical parameters of the Von Bertalanffy's growth equation for *Pomatomus saltatrix* in the Gulf of Gabes (IC = interval of confidence). *[Paramètres théoriques de l'équation de croissance de Von Bertalanffy chez* P. saltatrix *du golfe de Gabès (IC = intervalle de confiance).]*

	TL_∞ (mm) ± IC	k ± IC	t_0 ± IC
Females	477.9 ± 57.4	0.2131 ± 0.065	- 0.864 ± 0.412
Males	487 ± 59.4	0.1788 ± 0.051	- 1.089 ± 0.372
Combined sexes	483.2 ± 57.9	0.1951 ± 0.045	- 0.990 ± 0.314

RESULTS

Sexual cycle and bio-physiological indexes

The examination of the gonads permitted to discern males from females. No case of hermaphroditism has been

Table II. - Variations in the sex proportion (%) in accordance with size and χ^2 test of *Pomatomus saltatrix*, in the Gulf of Gabes (Test P = significance test) N.S = not significant, * = significant for $P < 0.05$, ** = highly significant for $P < 0.01$, *** = very highly significant for $P < 0.001$. *[Variations des proportions de sexes (%) en fonction de la taille et du test χ^2 chez* P. saltatrix *du golfe de Gabès (Test P = test de significativité) N.S = non significatif, * = significatif pour P < 0,05, ** = hautement significatif pour P < 0,01, *** = très hautement significatif pour P < 0,001.]*

	Females		Males		Tests		
Size class	N.	%	N.	%	χ^2	P	
106-125	3	42.86	4	57.14	0.143	0.705	NS
126-145	4	44.44	5	55.56	0.111	0.739	NS
146-165	7	30.43	16	69.57	3.522	0.061	NS
166-185	12	35.29	22	64.71	2.941	0.086	NS
186-205	11	57.89	8	42.11	0.474	0.491	NS
206-225	13	48.15	14	51.85	0.037	0.847	NS
226-245	37	57.81	27	42.19	1.563	0.211	NS
246-265	75	49.34	77	50.66	0.026	0.871	NS
266-285	70	50.00	70	50.00	0.000	1.000	NS
SL > 285	56	54.90	46	45.10	0.980	0.322	NS
Total	288	49.91	289	50.09	0.002	0.967	NS

Table III. - Monthly variations in the sex proportion (%) and the χ^2 test of *Pomatomus saltatrix* in the Gulf of Gabes (Test P = significance test). NS = no significant, * = significant for $P < 0.05$, ** = highly significant for $P < 0.01$, *** = very highly significant for $P < 0.001$. *[Variations mensuelles des proportions de sexes (%) et test χ^2 chez* P. saltatrix *du golfe de Gabès (Test P = test de significativité). NS = non significatif, * = significatif pour P < 0,05, ** = hautement significatif pour P < 0,01, *** = très hautement significatif pour P < 0,001.]*

	Months												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Tot.
N (♀)	23	15	15	11	18	29	24	31	35	32	32	23	288
N (♂)	26	17	15	27	26	20	17	15	23	25	50	28	289
Tot.	49	32	30	38	44	49	41	46	58	57	82	51	577
%(♀)	46.9	46.9	50	28.9	40.9	59.2	58.5	67.4	60.3	56.1	39	45.1	49.9
%(♂)	53.1	53.1	50	71.1	59.1	40.8	41.5	32.6	39.7	43.9	61	54.9	50.1
χ^2	0.184	0.125	0	6.73	1.45	1.65	1.20	5.57	2.48	0.86	3.95	0.49	0.002
T. (P)	0.668	0.726	1	0.009	0.228	0.199	0.274	0.018	0.115	0.354	0.047	0.484	0.967
	NS	NS	NS	**	NS	NS	NS	*	NS	NS	*	NS	NS

observed, indicating that bluefish, *Pomatomus saltatrix*, in the Gulf of Gabes is gonochoric. Among 577 individuals examined, we counted 289 males and 288 females. The proportion of males (50.1%) did not differ from the proportion of females (49.9%). The changes in sex ratio by size did not show any significant difference ($\chi^2 < 3.84$) (Tab. II). However, the monthly variations in sex ratio showed a high significant difference in April and a significant difference in November in favour of males and a significant difference in August in favour of females but, being weak, the samples did not allow us to propose any interpretation (Tab. III).

For both sexes, the two gonads of the bluefish, *Pomatomus saltatrix*, are functional. The sexual annual cycle is marked by seasonal variations in the activity of genital glands, liver and muscles. Among females, the weekly variations in the Gonad-Somatic Index (Fig. 2) showed a stage

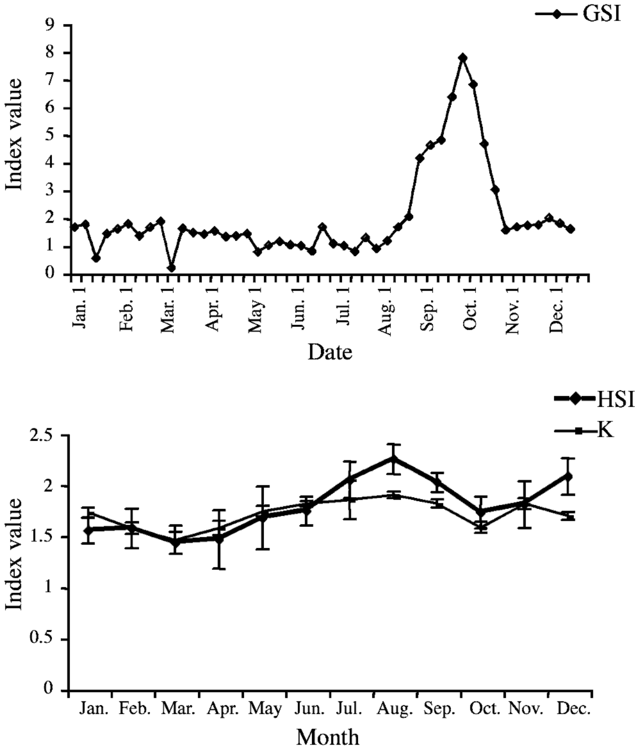


Figure 2. - Weekly variations in the GSI and monthly variations in the HSI (mean ± interval of confidence, IC) and the K (mean ± interval of confidence, IC) for bluefish females in the Gulf of Gabes. *[Variations hebdomadaires du RGS et variations mensuelles des RHS (moyenne ± intervalle de confiance, IC) et K (moyenne ± intervalle de confiance, IC) chez les femelles du tassergal du golfe de Gabès.]*

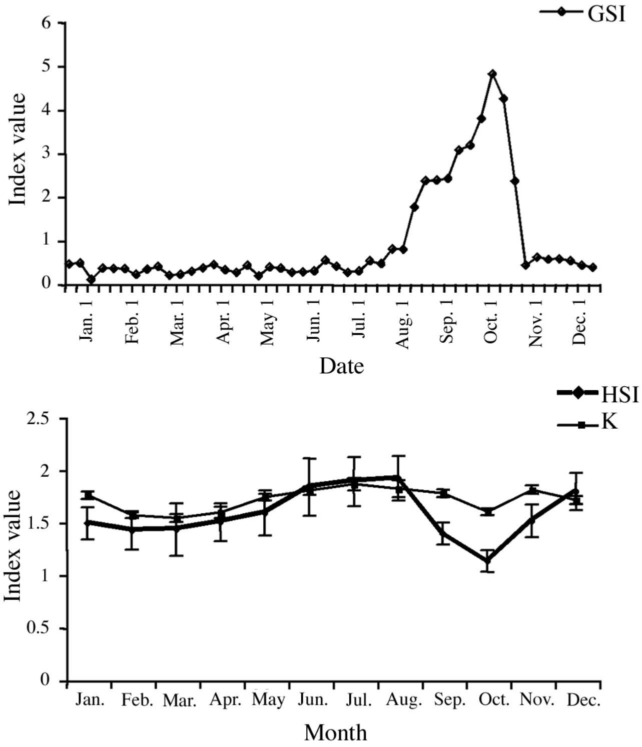


Figure 3. - Weekly variations in the GSI and monthly variations in the HSI (mean ± interval of confidence, IC) and the K (mean ± interval of confidence, IC) for bluefish males in the Gulf of Gabes. *[Variations hebdomadaires du RGS et variations mensuelles des RHS (moyenne ± intervalle de confiance, IC) et K (moyenne ± intervalle de confiance, IC) chez les mâles du tassergal du golfe de Gabès.]*

Table IV. - Standard length at first maturity (SL50 ± IC), standard length at 25% mature (SL25) and standard length at 75% mature (SL75), tests (c2) and the P test of significance: NS = no significant, * = significant for $P < 0.05$, ** = highly significant for $P < 0.01$, *** = very highly significant for $P < 0.001$, of *Pomatomus saltatrix* in the Gulf of Gabes. *[Longueur standard à la première maturité sexuelle (LS50 ± IC), longueur standard des 25% matures (LS25) et longueur standard des 75% matures (LS75), tests (c2) et le test P de significativité : NS = non significatif, * = significatif pour P < 0,05, ** = hautement significatif pour P < 0,01, *** = très hautement significatif pour P < 0,001, chez* P. saltatrix*, du golfe de Gabès.]*

Parameters	Females	Males	Combined sexes
r	0.1583	0.1291	0.1188
- r L50	-27.10	-23.37	-20.94
Correlation	0.99	0.99	0.99
SL50 (mm)	171.2 ± 2.35	181 ± 1.76	176.3 ± 2.55
SL25 (mm)	164.3	172.5	167
SL75 (mm)	178.1	189.5	185.6
Calculated χ^2	2.09	1.09	3.57
Theoretical χ^2	26.3	26.3	27.6
Test (P)	0.999	1	0.999
	NS	NS	NS

of pre-maturation that spreads from the first week of August (0.87) to the third one (1.65), followed by a fast maturation, a phase marked by a considerable increase of the GSI from the last week of August (2.03) to the beginning of October (7.75). The spawning, an event pronounced by a gradual decrease of the GSI from 7.75 to 1.54, occurs in October-November. The last stage (sexual rest) spreads from December to July.

The different stages of the genital cycle described among the females are found practically among the males as well (Fig. 3). The phase of fast maturation of the gametes is located between the third week of August (0.77) and the third one of October (4.79). The laying of these gametes (milt) occurs from the third week of October to the second one of November. The sexual inactivity phase (sexual rest) spreads from mid-November to July. Hence, the sexual cycles of the two sexes are synchronous but the values of the GSI are higher in females compared to males.

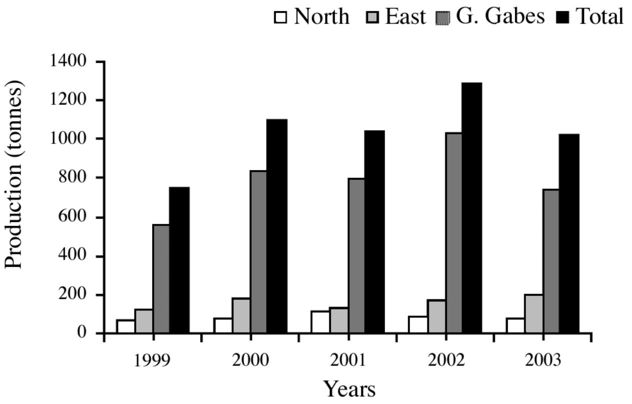


Figure 4. - Production of *Pomatomus saltatrix* by region, in Tunisia. *[Production de* P. saltatrix *par région, en Tunisie.]*

In the Gulf of Gabes, bluefish saved some reserves in liver as well as in muscles. The Hepatic-Somatic Index (HSI) and the condition coefficient (K) gradually increased from April to August. In September-October, a few weeks before the spawning of the species, the two indexes showed a decrease. The one of the HSI, more marked among males, was estimated to 41.16% and 23.19% for males and females respectively. The variations in the coefficient K were not very perceptible and its decrease had less importance (~ 14% for both sexes). Hence, it seems that the changes in the HSI and the K are associated with the sexual cycle (Figs 2, 3).

The changes in the proportion of the mature individuals showed that at a size (SL) < 165 mm, no individual, whatever its sex, was mature and that in a size (SL) > 205 mm, all observed individuals were mature. The results obtained by the application of the logistical function showed that size at first maturity (L50) was 171.2 mm for females, 181 mm for males and 176.3 mm for the two sexes combined. The χ^2 test did not show any significant difference between the theoretical proportions and the observed ones of matures (Tab. IV).

The theoretical ages at first sexual maturity were respectively 2.4, 1.9 and 2.1 years, for males, females and combined sexes respectively.

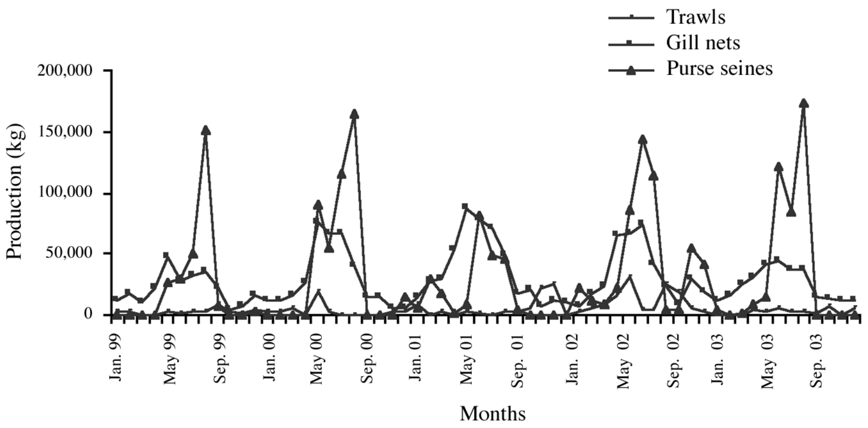


Figure 5. - Monthly production of *Pomatomus saltatrix* by gear, in the Gulf of Gabes (1999-2003). *[Production mensuelle de* P. saltatrix *par engin, dans le golfe de Gabès (1999-2003).]*

Table V. - Production of *Pomatomus saltatrix* in the Gulf of Gabes in weight and number, mean total length (TL_m ± IC), mean total weight (TW_m ± IC) and percentage of the production in 2002 and 2003 by gear and temporal stratum. *[Production de* P. saltatrix *dans le golfe de Gabès en poids et en nombre, longueur totale moyenne (TL_m ± IC), poids total moyen (TW_m ± IC) et pourcentage de la production en 2002 et 2003 par engin et par strate temporelle.]*

		Pr. (tonnes)	N. individuals	TLm (cm)	TWm (g)	Pr. (%)
Pre-season						
Gill nets	2002	60.107	279,338	30.2 ± 0.012	215.2 ± 0.278	49.69
	2003	84.934	36,923	30.6 ± 0.014	230.0 ± 0.342	80.61
Purse seines	2002	42.772	243,692	28.1 ± 0.014	175.5 ± 0.214	35.36
	2003	15.512	101,548	27.2 ± 0.006	152.8 ± 0.093	14.72
Trawls	2002	18.077	264,974	19.3 ± 0.020	68.2 ± 0.218	14.95
	2003	4.914	36,566	26.0 ± 0.012	134.4 ± 0.191	4.66
Season						
Gill nets	2002	247.368	1,909,464	25.2 ± 0.005	129.5± 0.087	36.98
	2003	159.716	578,917	32.1 ± 0.016	275.9 ± 0.358	28.21
Purse seines	2002	366.168	2,905,598	25.1 ± 0.004	126.0 ± 0.055	54.73
	2003	393.570	3,140,735	24.9 ± 0.004	125.3 ± 0.061	69.52
Trawls	2002	55.458	1,119,029	18.1 ± 0.005	49.6 ± 0.053	8.29
	2003	12.812	301,526	17.3 ± 0.009	42.5 ±0.066	2.26
Post-season						
Gill nets	2002	81.227	444,910	28.3 ± 0.012	182.6 ± 0.272	33.97
	2003	50.400	162,068	34.5 ± 0.010	311.0 ± 0.270	100.00
Purse seines	2002	104.677	570,076	28.3 ± 0.011	183.6 ± 0.257	43.77
	2003	0	0			
Trawls	2002	53.235	489,333	23.0 ± 0.016	108.8 ± 0.145	22.26
	2003	0	0			

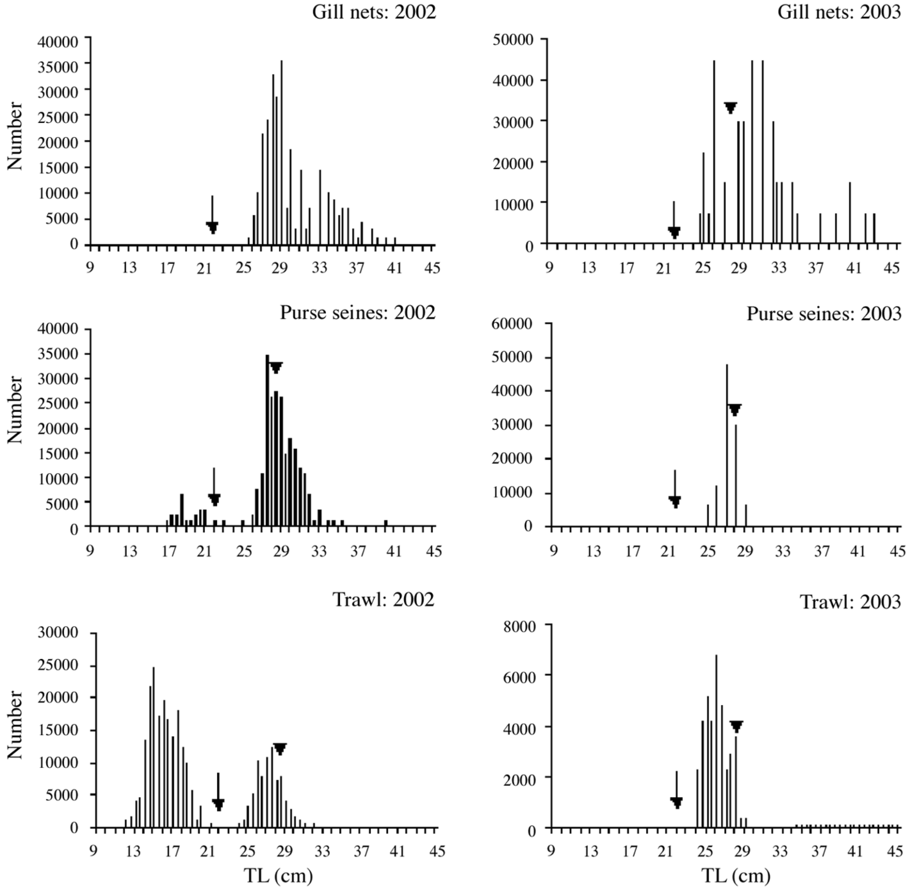


Figure 6. - Length-frequency distribution of *Pomatomus saltatrix* landed in the Gulf of Gabes by gear, in the pre-fishery season (2002, 2003). Length at first maturity = 22.1 cm, legal size of capture = 27.7 cm. *[Distribution des longueurs-fréquences de* P. saltatrix *débarqué dans le golfe de Gabès par engin, pendant la présaison de pêche (2002, 2003). Taille à la première maturité = 22,1 cm, taille légale de capture = 27,7 cm.]*

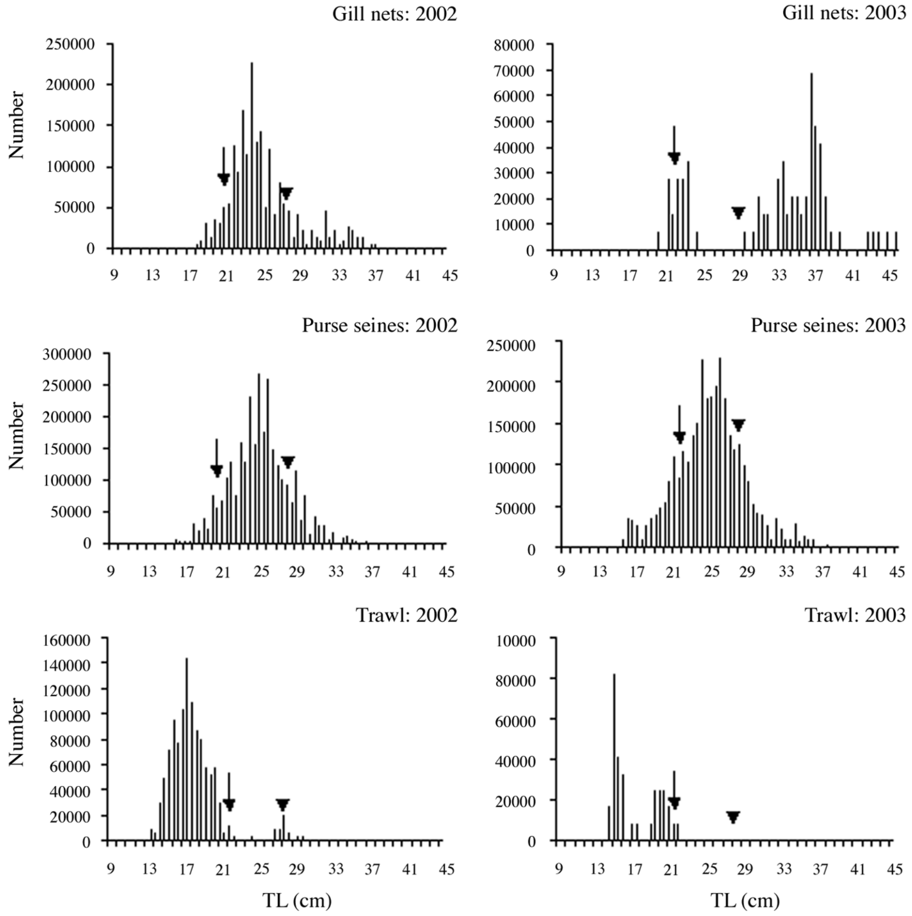


Figure 7. - Length-frequency distribution of *Pomatomus saltatrix* landed in the Gulf of Gabes by gear, in the fishery season (2002, 2003). Length at first maturity = 22.1 cm, legal size of capture = 27.7 cm. *[Distribution des longueurs-fréquences de* P. saltatrix *débarqué dans le golfe de Gabès par engin, pendant la saison de pêche (2002, 2003). Taille à la première maturité = 22,1 cm, taille légale de capture = 27,7 cm.]*

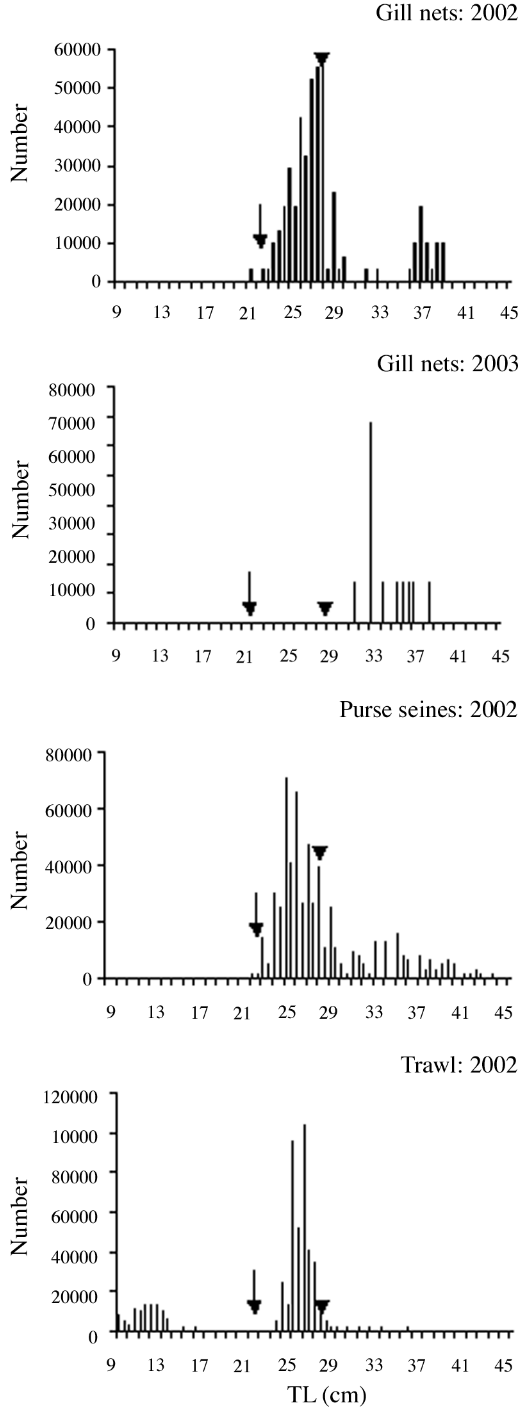
Fishing

In Tunisian waters, bluefish is caught all year round at several depths depending on the fishery gear. The annual catches varied between 747 and 1,285 tonnes from 1999 to 2003. The lowest catches corresponded to the coldest months. In spite of these seasonal and annual fluctuations, the production was important, especially in the Gulf of Gabes (Fig. 4). In this zone, the gill netters were active all year round in shallow waters and their contribution was more or less regular. The trawlers operating at depths above 50 m caught the bluefish as no-target species and their landings were generally not important. The purse seines, the action of which was limited to the fishery season (law of 1995), provided the essential of the production (approximately 50%) (Fig. 5). The peak observed in the curve always coincides with the fishery season and that is due to the activity of the purse seines.

Table VI. - Percentage in number and in weight of juvenile bluefish individuals and of individuals illegally caught by the three fleets in use in the Gulf of Gabes, by temporal strata, in the production of 2002-2003. *[Pourcentages en nombre et en poids du tassergal juvénile et des tassergals illégalement capturés par les trois types d'engins en usage dans le golfe de Gabès, par strate temporelle, dans la production de 2002-2003.]*

		Pre-season	Season	Post-season	Tot (02-03)
Total	N.	1,295,347	9,955,268	1,666,386	12,917,002
Juveniles	N.	211,687	3,038,030	100,729	3,350,447
	%	16.34	30.52	6.04	25.94
Illegals	N.	575,695	7,984,867	1,109,558	9,670,120
	%	44.44	80.21	66.58	74.86
Total	W. (t)	226.316	1235.091	289.539	1,750.947
Juveniles	W. (t)	7.544	170.926	1.613	180.084
	%	3.33	13.84	0.56	10.28
Illegals	W. (t)	58.807	758.189	133.030	950.028
	%	25.98	61.39	45.95	54.26

Landings of the bluefish in 2002 and 2003 were respectively 1,029 t and 722 t corresponding to ~ 8,226,414 and ~ 4,690,590 individuals respectively. The greater part of the production occurred in the fishery season and the size gap among the landed individuals could reach about 15 cm (Tab. V). The size of the individuals caught by both the gill nets and by the purse seines was often superior to the length at first maturity (TL50 = 22.1 cm) but sometimes below the legal size of capture (TL = 27.7 cm) (Figs 6, 7, 8). The individuals seized by trawls were generally juvenile and their size was often much inferior to that of first maturity and to the legal size of capture. Apart from that, the purse seines, illegally used out of season, could land an important quantity, sometimes exceeding 100 t (post-fishery season 2002). The percentage of juveniles captured by all gears together in 2002-2003 was 25.94% in number and 10.28% in weight, even though the percentage of individuals illegally caught was 74.8% in number and 54.26% in weight (Tab. VI).


Gill nets: 2002

Gill nets: 2003

Purse seines: 2002

Trawl: 2002

Figure 8. - Length-frequency distribution of *Pomatomus saltatrix* landed in the Gulf of Gabes by gear, in the post-fishery season (2002, 2003). Length at first maturity = 22.1 cm, legal size of capture = 27.7 cm. *[Distribution des longueurs-fréquences de* P. saltatrix *débarqué dans le golfe de Gabès par engin, pendant la post-saison de pêche (2002, 2003). Taille à la première maturité = 22,1 cm, taille légale de capture = 27,7 cm.]*

DISCUSSION

In the Gulf of Gabes, the population of the bluefish, characterized by a balance of sexes, reproduces in autumn (Oct-Nov). The spawning is probably associated with the water temperature in this season. According to Sabates and Martin (1993), in the North-western Mediterranean the spawning of bluefish occurs when the temperature of surface water is about 25°C. This temperature often prevails in the South-east of Tunisia in autumn (September, October and November).

Female bluefish are sexually slightly more precocious than males in length and in age. At first maturity, female size is 17.1 cm and that of males is 18.1 cm. The age at first sexual maturity is 1.9 and 2.4 years, respectively, for females and males. Although this phenomenon is rare, it is also observed among bluefish living on the north-eastern coasts of the United States, where the size at first sexual maturity is 33.4 and 33.9 cm respectively for females and males (Salerno *et al.*, 2001).

In the Gulf of Gabes, bluefish (combined sexes) becomes sexually mature when it reaches 17.6 cm SL (22.1 cm TL). This length is smaller than the size at first maturity of the bluefish in other areas. The literature indicates that this size varies from 25 cm TL in South Africa (Van der Elst, 1976) to 43 cm TL in Senegal (Conand, 1975). Champagnat (1983) suggested that differences in size at first maturity could lead to differences in growth. In fact, in southern Brazil, where the stock is relatively fast growing, the length at first maturity of the bluefish is between 35 and 40 cm (Haimovici and Krug, 1992) but in the Gulf of Gabes where the bluefish has moderate growth, the length at first maturity is 22.1 cm. The weak growth observed among the bluefish (and other species) in the Gulf of Gabes could be due to the lack of preys (Dhieb, 2001), the low depths of the continental shelf, the intensive fishing practised in the zone (Bradaï, 2000) and the pollution of the ecosystem caused by the industrial refuse (Hamza, 2003).

According to Bougis (1952), the skinny fish, belonging to the *Gadus* type, save some lipid reserves in their liver to get ready for reproduction. These lipids are transferred to the gonads during the maturation of the gametes. Among these fish, the HSI, shows an increase before the maturation stage, then it gradually decreases. The fat fish, whose muscular mass shows a considerable increase, belong to the *Mullus* type. Among these fish, the coefficient K and the GSI are almost parallel to each other as the reserves saved in the muscles are transferred to the liver where they are transformed before being conveyed to the gonads. Since, in the Gulf of Gabes, the bluefish manifests roughly all these phenomena, it presumably belongs to an intermediate type between the two extreme types described by Bougis (1952).

The adipose reserves saved in the muscle and its small increase during the fishery season (period of May through August) contributes probably to a better organoleptic quality of the flesh which is highly appreciated by the consumers. The closure of fishery season by the end of August, two months before the reproduction of the bluefish, allows it to rejoin its spawning areas.

The legal size of capture guarantees a safety margin of 4.4 cm SL (difference between legal size, 22 cm, and length at first maturity (SL50), 17.6 cm) and allows all individuals to lay at least once in their life since SL99% mature = 21.5 cm. However, it is worth noting that in the Gulf of Tunis (North of Tunisia) the smallest really mature female observed had a length of 31.5 cm SL and the smallest really mature male observed had a length of 26 cm (Kedidi, 1975), but since that time, the survey has not been carried on. We suggest a deeper investigation of the bluefish in the north.

Investigation conducted on the annual landings of the bluefish showed that the production of this species in the Gulf of Gabes is very important in terms of quantity and it is even more important in terms of commercial value considering its expensive price. Frequently, the annual production is submitted to fluctuations which could be due to the fact that this species is migratory. An additional fluctuation could be seasonal and due, in one hand to the variable abundance of the bluefish in relation with the climatic conditions and, in the other hand, to the orientation of the gears toward the fishing of other species.

The gill nets have a quasi-regular production that reflects the seasonal abundance of the bluefish on the coasts of the Gulf of Gabes. This abundance appears relatively high during the fishery season that corresponds to the hottest months, middling during the post-fishery season that corresponds to the warm months and low in the pre-fishery season that corresponds to the cold season (Tab. V). The purse seines, normally conceived for catching small pelagic fish, produce considerable quantities of bluefish during the fishery season and some quantities of this species out of season (e.g. 149.449 t in 2002) but this production is illegal because these gears are the only ones concerned by the temporal limitation, that is the fishery season of the bluefish. The production of the trawls represented 12.3% and 2.45% in 2002 and 2003 respectively (Tab. V). This production seems to be exceptionally low or even negligible in weight, but seeing the number of individuals seized, it becomes very significant. In fact, in 2002, the trawls caught 264,974 individuals in the pre-fishery season and 1,119,029 individuals in the fishery season, before the spawning period. As the majority, if not all, of these individuals were juvenile (mean TL < 22.1 cm), the use of trawls could have a negative impact on the bluefish population in the Gulf of Gabes. Moreover, the steep fall in the production from 1,029 to 722 t in 2002-2003, may be due to irresponsible fishing.

The importance granted to the exploitation of the bluefish is proved by the particular interest taken in its fishing. The choice of the fishery season is based on the good conditions of the summer, abundance and the plumpness of the species. The legal size of capture, although empirically determined, is suitable to the bluefish in the Gulf of Gabes. Concerning the size of the meshes, they appear sufficiently large for the gill-nets (30 mm) while the meshes (12 mm) of the purse-seines used for pelagic fish as sardines can induce some mistaken fishing. Since the measurements of the meshes can be determined only after several experiments to be considered as an appropriate selective factor (this is something that hasn't been done up to now), we propose to use temporarily nets with identical meshes to those of the gill nets, which rarely catch juvenile individuals. The majority of the individuals fished have a size ranging from the length at the first maturity to the legal length of capture, except in the case of individuals taken by the trawls; these are often juvenile and without commercial value.

In these conditions the renewal of the stock may be ensured but the infringement of one regulation (legal size) encourages the breaking of others (fishing at illegal depths and out of season), which is sometimes the case. Consequently, we reassert that it is recommended to abide by the restrictions which have been taken in order to protect the stock. The fishermen should be aware that even though the bluefish now constitutes a considerable source of food and economic resource in the Gulf of Gabes, it is absolutely necessary to exploit it reasonably to assure its durability.

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